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Tool and Process for Casting a Shaped Part for the Production of a Turbine Blade

FIELD OF THE INVENTION

[0001] The present invention relates to a tool for casting a shaped part for the production of a turbine blade, in which tool plural tool blocks, assembled with positive engagement in a predetermined manner, form for the shaped part a cavity into which a flowable material, particularly wax, can be introduced by means of one or more access apertures. The invention furthermore relates to a process for the production of a shaped part for a turbine blade with such a tool.

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BACKGROUND OF THE INVENTION

[0002] In the development of turbine blades, numerous tests and adjustments are to be performed in the different development stages, such as the development of casting, machining or manufacturing, and can affect the original tool development. Just differences between the aerodynamic model calculations and the later real properties of the finished system can make it necessary to prepare a new set of tools for the production of the initial shaped parts.

[0003] In the production and development process of a turbine blade, the shape of the turbine blade which is correct for the requirements is first calculated as a three-dimensional model. Injection molding tools are produced from this model, which make possible the casting of a shaped part with the calculated three-dimensional shape. These injection molding tools are as a rule assembled from several tool blocks, which, assembled with positive engagement in a predetermined manner, form a cavity for the shaped part. Molten wax is injected under high pressure through one or more access apertures into the cavity formed. The injected wax hardens after cooling to a shaped part, having the shape

predetermined by the injection molding tools. The tool blocks are then re-moved. A ceramic casting mold for the later precision casting of the turbine blade is produced in a known manner with the shaped part prepared in this manner.

[0004] The production of the tool blocks for the injection mold is very expensive, since they are as a rule made of steel and are to define the shape of the later turbine blade as precisely as possible. Furthermore, the positive closure between the individual tool blocks must achieve a sufficient sealing effect against the wax injected under high pressure.

[0005] It is precisely the dimensioning and production of the first row of inlet guide blades of the turbine sets very high requirements, since the flow path of the hot gases is very sensitively affected by this first row. A minimum deviation of the attack angle of these guide blades from an ideal value already leads to a clear pressure increase or pressure decrease in the gas turbine, and this can considerably affect the efficiency. In the case of such an undesired deviation, a new shaped part with a correspondingly changed attack angle therefore has to be produced, and for this the production of a completely new injection molding tool is necessary. Furthermore, several additional tolerances are to be considered during the whole production process, and likewise can exert a substantial effect on the flow path of the hot gas. As examples, there may be mentioned in this connection, scatter in the processing of the casting, or deviations in coating thickness. Such deviations are not yet known in the initial dimensioning of the shaped part, and can therefore likewise give rise afterwards to a change of the geometry of the injection molding tools.

SUMMARY OF THE INVENTION

[0006] Starting from this state of the art, the invention has as its object to provide a tool and also a process for the production of a shaped part for a turbine blade, making it possible to accomplish an easy change of the leading edge geometry or of the attack angle of the turbine blade without a complete new production of the injection molding tool.

[0007] The tool according to the invention for casting a shaped part for the production of a turbine blade is assembled from several tool blocks. These tool blocks, when assembled with positive engagement or pushed together in a predetermined manner, form a cavity for the shaped part, into which cavity a flowable material, such as, for example, molten wax, can be introduced through one or more access openings provided therefor. The present tool is distinguished in that at least one tool block receives a rotatable or displaceable insert or inset, which has one surface bordering on the cavity and which can be fixed in different positions and/or orientations with respect to the tool block, so that different cavity geometries or cavity volumes are formed in the different positions and/or orientations of the insert or inset.

[0008] The insert or inset here preferably consists of the same materials as the tool blocks and can be inserted into these with positive engagement. By means of the possibility of producing different cavity geometries in the different positions and/or orientations of the insert or inset, a later adaptation of the geometry of the shaped part can be undertaken by renewed introduction or injection of the liquid material into the cavity with a correspondingly changed position and/or orientation of the insert. A new production of the whole injection molding tool, i.e., the shaping inner surface of the respective tool blocks, is thereby no longer necessary. One or more inserts or insets can of course be provided in one or more tool blocks, and can be arranged by the person skilled in the art corresponding to the intended possibility of adjustment or displacement. The inserts are then fixed with a suitable fixing means in the desired position before filling with the flowable material, so that their position and/or orientation no longer changes during the filling and hardening process of the flowable material. The fixing of the one or more inserts preferably takes place by means of securing pins which engage in correspondingly provided recesses in the respective tool blocks. The securing pins are pushed in through corresponding apertures in the insert. The corresponding recesses in the tool blocks are constituted, according to the desired step spacing at which displacement is possible, as a correspondingly fine hole pattern.

[0009] The insert(s) is/are preferably embodied such that they determine the surfaces of the shaped part to be produced, which determine or contribute to the course of the hot gas path of the turbine blade. A particularly advantageous embodiment here relates to the arrangement of two inserts or insets in opposed tool blocks. The inserts or insets are here constituted such that when assembled they form a cylindrical insert unit for the determination of the geometry of the blade. The insert unit assembled from the two inserts or insets is rotatable around its longitudinal axis in the tool blocks and can be fixed in different rotational positions. Different attack angles of the blade can be implemented by different rotational positions of the insert unit.

[0010] Fixing possibilities are preferably provided at such spacings that the attack angle can be changed in angular steps of 0.25-0.5°. In this manner, a shaped part with an altered attack angle can be produced very quickly, simply and without new construction of the tool blocks, if during further development it should transpire that the originally designed attack angle did not fulfill the requirements for the hot gas path because of manufacturing tolerances.

[0011] Such an embodiment of the tool has the further advantage that shaped parts can also be produced therewith for turbine blades of different plants without having to prepare a separate respective tool. For example, turbine blades for turbine plants with other flow properties or other mass flows, as particularly arise with gas turbines operated with different fuel types, can be produced hereby with one and the same tool.

[0012] For an adjustment of the parting lines in the tool on changing the position and/or orientation of the insert, adapters can be present, which displace the parting lines and/or compensate for a possible play between the insert and the tool block. It is also conceivable here to already provide corresponding, preferably wedge-shaped, interspaces between the inserts, into which the corresponding adapters can be inserted after the positioning of the inserts.

[0013] In a further possibility of embodiment of the present tool, an insert which is displaceable along an axis is provided in a tool block which substantially serves to define

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the shape of the blade platform and of the blade foot, the height of the blade platform being determined by the displacement position of the said insert. The displacement axis here corresponds to the z-direction, which on insertion of the later turbine blade corresponds to the radial direction.

[0014] In the production of the shaped part, the individual tool blocks are assembled, preferably pushed together, the insert(s) or inset(s) are brought into a position and/or orientation with which the desired geometry of the cavity or of the later shaped part is produced, and are fixed in this position on the tool blocks. Molten wax is then injected under high pressure into the thus produced cavity, and is solidified there by cooling. After solidification, the tool blocks with the associated inserts or insets are separated from the hardened wax shaped part. A separation of the inserts from the shaped part is facilitated by the adapters already described.

[0015] The tool and also the accompanying process for injection molding a shaped part for the production of a turbine blade is particularly suitable for the adjustment of the attack angle of the blade of the turbine blade or for the adjustment of the height of the blade platform of the turbine blade. The tool offers particular advantages in cases in which a high number of adjustments have to be undertaken during the development of the turbine blade. The more adjustments are required, the more advantages the present process offers, since a new injection molding tool does not have to be produced for each adjustment. The adjustments can instead be implemented by simple adjustment of the insert within the tool.

[0016] The tool or the accompanying process principally relate to the production of shaped parts made of wax. It is, however, obvious to the person skilled in the art that other meltable materials other than wax can be used for the production of the shaped parts with the present tool. Furthermore, the material of the tool blocks play no essential part for the invention, so that materials are available to the person skilled in the art for this, as required corresponding to the respective application. The external embodiment of the individual tool blocks can likewise be undertaken here according to the known state of the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The invention is again briefly described hereinbelow using an embodiment example in connection with the accompanying drawings, without limitation of the general concept of the invention.

Fig. 1 is a diagram showing an example of an injection molding tool which is assembled from several tool blocks;

Fig. 2 is a diagram schematically showing the construction of a turbine blade; and

Fig. 3 is a diagram showing an example of the embodiment of an inset in a tool according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Fig. 1 shows an example of an injection molding tool for the production of shaped parts for turbine blades. The tool consists of a baseplate 15 on which the four tool blocks 1-4 are arranged. The baseplate and the tool blocks consist of a steel material. The tool blocks can be displaced in corresponding guides of the baseplate 15, as can be seen from the Figure. The inner surfaces of these tool blocks 1-4 are shaped such that after assembly they form a cavity which provides the shape for the shaped part to be manufactured.

[0019] The individual tool blocks are in this example pushed together in the respective guides so that with positive engagement they seal off the cavity from the exterior. A wax injection aperture 6 is in this example provided in the baseplate 15, and the injected liquid wax reaches the cavity 5 by means of corresponding channels (shown dashed). The wax is injected under high pressure here and is solidified by cooling in the cavity. The tool blocks 1-4 are then separated from the wax shaped part produced in this manner. This separation takes place by pulling apart the individual tool blocks in the guides. Corresponding handles 16 are provided on the tool blocks for this purpose in the present

example. An arrangement of this kind is already known from the prior art, but can also be used for the tool of the present invention, at least one bounding surface of the cavity 5 formed by the tool blocks 1-4 then being formed by a surface of an insert or inset, not visible in this illustration.

[0020] With such a tool, shaped parts for turbine blades are manufactured, such as are seen in Fig. 2, for example. This Fig. 2 shows the typical components of a turbine blade 10: the blade 11, a blade band 13, as well as a platform 12. For the production of a shaped part constructed in this manner, the inner surfaces of the tool blocks 1 and 2 of Fig. 1 are embodied for determining the suction and pressure side of the blade 11, the tool block 3 is embodied for determining the shape of the blade platform 12, and the tool block 4 is embodied for determining the shape of the blade 13.

[0021] With a fixed present geometry of the inner surfaces of these tool blocks 1-4, no possibility exists of a subsequent adjustment of the geometry, for example for the production of another attack angle of the blade. Such a possibility of adjustment is implemented with the tool according to the invention, which is shown in a possible variant embodiment in Fig. 3. Fig. 3 here shows only a portion of the tool with the tool blocks 1 and 2 for determining the blade 11. The further tool blocks 3 and 4 corresponding to Fig. 1 are embodied as known from the state of the art.

[0022] In contrast to the known tools of the prior art for the production of shaped parts for turbine blades, the present tool has in this example two tool blocks 1 and 2, which respectively receive an insert 7 or 8 with positive engagement. For this purpose, the inner surfaces of both the tool blocks 1 and 2 are correspondingly shaped. On assembly of the two tool blocks with their inserts or insets 7 and 8, a cylindrical insertion unit 9 is formed which is rotatable about its longitudinal axis within the tool blocks 1, 2, as is indicated in Fig. 3 by the arrow. The two inserts 7 and 8 here cooperatively form the geometrical shape for the blade 11, i.e., their surfaces bounding the cavity 5 are shaped corresponding to the pressure and suction side of the blade.

[0023] Optional attack angles of the blade 11 with respect to the platform 12 or to the blade band 13 can be produced by means of the rotatability of the insertion unit 9. The insertion unit 9 is fixed in the corresponding desired position with respect to the tool blocks 1 and 2 by means of securing pins (not shown in the Figure). The tool blocks 1 and 2 have a corresponding hole pattern for different settings for this purpose.

[0024] In this embodiment example, furthermore, a substantially wedge-shaped cavity is provided between the two inserts 7, 8 at the transition to the tool blocks 1, 2; interchangeable adapters 16 can be inserted into the said wedge-shaped cavity. These adapters 14 facilitate the dismantling of the individual tool blocks after the injected material has hardened.

[0025] The tool is embodied in a preferred embodiment such that the attack angle, i.e., the insert unit 9, can be rotated in steps of about 0.25-0.5° through a maximum angle of 2-3°, and can be fixed. This is sufficient for the development of a turbine blade, taking possible later adjustment changes into consideration.

[0026] In the same manner, a corresponding insert can be provided in the tool block 3, this time displaceably embodied in the direction of the blocks 1 and 2, in order to be able to adjust the height of the platform 12 of the shaped part. It goes without saying that other surfaces of the shaped part can also be changed or adjusted in this manner, if a corresponding movable insert is provided.

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